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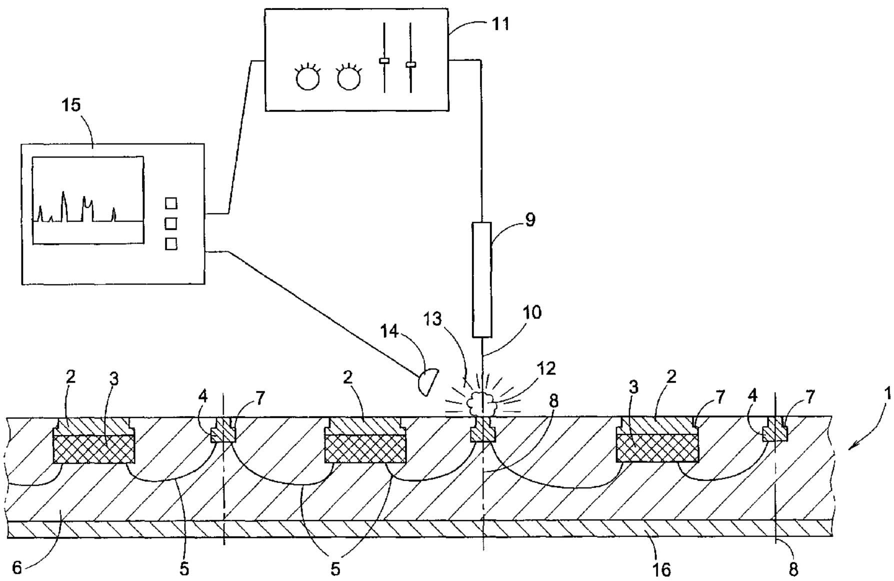
(54) Title: METHOD FOR CUTTING A COMPOSITE STRUCTURE COMPRISING ONE OR MORE ELECTRONIC COMPNENTS USING A LASER



(57) Abstract: A method and device for cutting a composite structure (1) comprising one or more electronic components (3), in particular integrated circuits, the method using a laser (9), wherein during the cutting of the material of the composite structure (1), a physical quantity relating to the cutting is measured and wherein the power of the laser (9) is adjusted depending on that quantity. The invention further comprises a method for testing ICs accomodated in a composite structure.

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Short title: Method for cutting a composite structure comprising one or more electronic components using a laser

The present invention relates to a method for cutting a composite structure comprising one or more electronic components, in particular integrated circuits, using a laser.
The cutting of materials using a laser is commonly known. Herein the laser removes material. Hereby, incisions are formed, and also parts of an object can be cut loose. Many different materials can thus be cut. For instance, from US-A-6 057 180 it is known to cut laser electrical connections on a wafer with one or more ICs with the use of a laser. Herein a narrow laser bundle is aimed at the electrical connection, whereby material of the electrical in connection is removed and the electrical connection is severed. Therein, the surrounding material (the passivation layer) absorbs the excessive laser energy so that the substrate of the wafer is not damaged.

In the present application, composite structure means a structure that comprises at least two parts made of different materials. In particular the composite structure relates to a lead frame with ICs that are encapsulated with plastic. If desired, the ICs are attached to a substrate. In cross-section this composite structure comprises a layer of plastic, at least one layer of chip material, such as e.g. silicon, and possibly one or more alternate layers of metal and/or other materials. Within the scope of the invention a composite structure may be a laminate as well as a composite of different materials.

One of the problems that occur during cutting of a composite structure consisting of different materials is that the various materials often respond very differently to the laser radiation.

Materials with a low melting point that absorb much of the radiation and also hardly transport heat, like for instance some plastics, will for instance be cut much faster but also less controllably than for instance metals with high melting points that reflect much of the laser radiation and also conduct heat quickly. Cutting with unaltered power of the laser could cause an uncontrolled evaporation of material, which must be avoided at all times with the often very small parts of ICs. In particular during cutting of encapsulated ICs the problem occurs that the encapsulating material - often a thermosetting plastic - requires a different quantity of energy to be cut than the metallic electrical connections. When such an encapsulated IC is cut with conventional laser cutting techniques the metal and/or plastic will be cut in a very uncontrolled way and smearing may occur whereby electrical contacts can be connected with each other undesirably.

The present invention aims at providing a solution for the above mentioned problems and thereto is characterized in that during the cutting of the material of the composite structure, a physical quantity relating to the cutting is measured, and that of that the power of the laser is adjusted depending on said physical quantity.

By measuring such a physical quantity during laser cutting, it can be determined which material is being cut by the laser at that moment. At the moment that changes in the measured physical quantity give rise thereto, the power of the laser can be adjusted from one first non-zero value to another non-zero value, in dependence of the material cut at that moment. In this way it is prevented that the laser "shoots through" at a material transition, thereby cutting big holes in the underlying material, or that, by smearing of metal, unwanted electrical contacts are made.

Per se, there is known in the state of the art a method for cleaning of paintings, wherein a laser irradiates the surface of the polluted painting, and at the same time the spectrum of the radiation emitted by the evaporated material is measured. The irradiation is continued until the measured spectrum corresponds to that of, for instance, the coating of varnish. At that moment the layer to be removed has been removed at the irradiation spot. Then the irradiation is interrupted and then a different, not yet cleaned, part of the painting is treated. Herein, there is no cutting of a composite material with electronic components, i.e. removing material in a part of a plane, that is curved or not, and makes an angle with the surface of the composite material. This angle is preferably >45°, and more preferably about 90°.

Adjusting the power of the laser can take place smoothly when the value of the physical quantity is changing smoothly. However, in practice the value of the physical quantity will often change steplike, i.e. every time the laser passes a material transition. In this case the power of the laser will also be adjusted steplike.

In this way it is possible to cut in a controlled way through the complete composite material in one cutting motion. As soon as the physical quantity measured shows that the nature of the material cut at that moment has changed, the power of the laser can be adjusted instantly to the new material. Of course the method according to the invention is also suitable for the partial cutting of a composite structure with one or more electronic components. For instance electrical connections can thus be cut in a reproducible way without cutting the complete structure.

In principle the physical quantity to be determined is not specifically limited. For instance the temperature of the material near the cutting location can be measured so that, taking into account the thermal conduction and the power of the laser, the specific heat of the cut material may be determined, which is an indication for the kind of the cut material and therefore a change of cut material could thereby observed. Also, for instance, the reflection of the laser light off the cut material could be determined, from which the reflection coefficient may be determined which is also an indication for the kind of the cut material.

Furthermore an additional radiation source may be pointed at the cutting location, and an absorptive strength of the reflected radiation may be determined, whereby a change of the evaporated material may be observed.

Preferably the physical quantity comprises radiation emanating from the composite structure. This radiation originates from atoms and/or molecules excited by the laser light. For instance the temperature can be derived from the total quantity of emitted radiation, which is - as described above - again an indication for the kind of material that is being cut at that moment.

In particular the spectrum of the radiation emanating from the composite structure is measured. The spectrum of the emitted radiation is specific for the kind of material that is being cut. The spectrum may be compared to set values or standard spectra and the like in order to observe changes thereof and therefore changes of materials to be cut. In practice the radiation is mostly emitted by material evaporated by the laser radiation. Spectroscopic characterization of this evaporated material is a direct identification of the cut material, whereby many different substances may be recognized, because every substance shows a characteristic spectrum. Furthermore spectroscopy is a very fast measuring method.

The laser radiation may be supplied to the composite material in a continuous way. This means that a continuous laser may be used. The power density thus to be gained however is in general too small for a controlled cutting process. In this way it is possible is that the energy is spread too much to the adjacent material. Reducing the power of the laser can decrease this possibility, but this has the disadvantage that the complete cutting process takes place too slowly.

Therefore it is preferred that the laser is a pulsed laser. This offers the possibility to easily control the supplied laser energy at a high power, and therefore also the effect thereof on the composite material to be cut. After each pulse, its effect may be determined without the laser cutting any further in the meantime.

The type of laser used is not specifically limited. The laser radiation should be absorbed well by the materials to be cut, or at least by one of the materials to be cut. Furthermore the laser should be such that the power can be adjusted, preferably in as large a range as possible. Pulsed lasers offer advantages here because the power of the laser can be changed by changing the energy per pulse as well as by changing the time between two pulses.
Advantageously the wavelength of the laser used is smaller than 400 nm. In practice the smallest useful focus diameter of a laser beam is equal to twice the used wavelength. Dependent on the dimensions of the smallest parts to be processed, a laser with a short wavelength gives the most possibilities.

The invention further provides a device for the cutting of a composite structure comprising one or more electronic components, in particular integrated circuits, the device at least comprising:

- A laser,
- Control means for controlling the power of the laser,
- Support means for the composite structure,
- Transport means to move the composite structure and the laser with respect to one another,

the device being characterized in that it further comprises measuring means for measuring a physical quantity relating to the cutting during the cutting of the material of the composite structure.

By means of this device, such a composite structure may be cut. Thereto the composite structure is supported by means of the support means, and the composite structure and the laser are moved with respect to one another in such a way that the laser can introduce the desired cutting lines. Preferably the support means are a support mold, whether or not provided with vacuum suction means, or a carrier film, for instance an adhesive carrier film. Such a carrier film may be clamped for instance between two rolls or clamps. During the cutting of the material of the composite structure, the measuring means measure a physical quantity that relates to the cutting. On the basis of the measured value of that quantity the power of the laser may be adjusted.

In a special embodiment of the device according to the invention the measuring means comprise means for measuring a part of the spectrum of radiation emanating from the composite structure. For instance, near the cutting location light-sensitive elements, for instance photodiodes, or light conducting elements, for instance optical fibers are mounted. These light-sensitive or light conducting elements are for instance connected to a spectroscope for measuring of the part of the spectrum. For instance the complete visible spectrum may be measured, but also, for example, only one or a few radiation peaks that are characteristic for the material to be processed.

Although, as described above, the power of the laser can be adjusted manually in dependence of the value of the physical quantity it is preferred when the control means for controlling the power of the laser are coupled to the measuring means. Hereby the cutting operation may simply be automated and a fast and reliable control of the power of the laser is possible. Thereto for instance a control assembly may be present, which is designed to control the means concerned. Such a control assembly may comprise a data processing unit, like a computer and the like, to control matters in a suitable way.

Further the invention provides a composite structure, comprising one or more electronic components in particular integrated circuits, obtainable by a method according to the invention. In particular, with help of a working method according the invention, it here concerns cut covered electronic components like ICs. These show very intact cutting faces without smearing of metal.

Finally, the invention provides a method for testing electronic components accommodated in a composite structure, the method comprising the following steps:

- Providing a composite structure, comprising a lead frame onto which at least one electronic component has been mounted, and at least two contact pads, wich are each connected to an electronic component and to at least one other contact pad, wherein the lead frame, the at least one electronic component and the contact pads are at least partially covered with encapsulating plastic;
- Cutting of the electrical connections between each of the contact pads belonging to at least one electronic component, and the other contact pads; and
- Testing of the electronic component thus insulated electrically.

This method has an important advantage that during the testing the mechanical strength of the encapsulating plastic may be used. Herein it is not necessary to sever the electrical connections between the contact pads prior to the circuit testing.

Here, cutting means the removal of material in any way, such that an electrical connection is severed. This may relate to cutting in a narrow sense, but also sawing, grinding, etc.

In the state of the art, either these electrical connections between the contact pads are severed prior to the encapsulation of the component, or these connections are not severed in advance, but the electronic components are first cut from the composite structure before they are tested. The first method has the disadvantage of a poor strength of the lead frame with severed connections between the contact pads. Thereby deformation of the lead frame can easily occur with risk of measurement errors. The second method has the disadvantage that each component cut loose must be tested separately. Especially with large numbers of electronic components per lead frame this is very labor-intensive. The method according to the invention however combines the advantages of both methods without their disadvantages. Of course it is also possible to test more than one electronic component in a composite structure at the same time. Thereto each of the contact pads of the components to be tested must be electrically insulated from the other contact pads.

Here it is noted that contact pads in a lead frame basically are all connected to each other. In fact they are projections on the metal lead frame. Often they are present in groups of two. In any way the severing of the electrical connections between each of the contact pads belonging to an electrical component and other contact pads amounts to the severing of the electrical connection between the contact pads and the lead frame. Thus the contact pads are automatically insulated from the other contact pads.

In a preferred embodiment, this method further comprises the following steps:

- Marking of the tested electronic component, dependent on the result of the testing; and
- Cutting the tested and marked electronic component loose from the composite structure.

For instance the plastic of the one or more approved electronic components may be marked with a code different from that of rejected electronic components. Amongst other things, this can take place with a color marking, an incision, but also by storing the coordinates of those components. In that way a correct selection later on is much simplified.

Advantageously the method further comprises the following steps:

- Mounting the composite structure, at one side thereof onto support means; and
- Mechanically disconnecting the electrically isolated electronic component from the composite structure.

This offers the advantage that already separated electronic components are obtained, that however still can be treated as a whole, because they are held together with the help of the support means on one site of the composite structure.

Advantageously the support means are selected from a carrier film, a supporting mold, a support mold with vacuum suction means, or a combination thereof. For instance, this offers the possibility to apply the result of the test to the carrier film, for example by applying a color marking on the carrier film near an approved component. Further, the one or more mechanically and electrically insulated components may still be processed and moved as a whole, by taking out the carrier film and/or the support mold, with the electronic components attached thereon.

The carrier film may comprise any suitable adhesive foil. In this connection the concept of foil must be interpreted broadly, and includes also a thin layer of a material with certain rigidity, which material is provided with an adhesive. The support mold can be a plate with substantially the shape and dimensions of the composite structure, or somewhat larger. The mold may be provided with holes or channels. Via these holes or channels an air exhaust can be connected, that can suck the composite structure, if desired provided with a carrier film, to the supporting mold.

Advantageously the step of cutting of the electrical connections and the step of the mechanical disconnection take place in one processing step. This has the advantage that only one separating operation is necessary, whereby the risk of movement of components between a plurality of cutting and separating operations is excluded, and also that a better quality of the separating surface is possible.

Preferably the step of cutting the electrical connections is brought about using a laser. As already described above, with such a method a very good quality of the cutting faces is possible, without the risk of smearing of metal. The laser may be applied in many different ways. It is e.g. possible to do tests prior to the production in order to determine the correct power of the laser. Due to this, no further peripherals are needed for controlling the laser in the production process.

It is also possible to let the laser work as it were phased. That is possible for instance, with a pulsed laser, or by having the laser go over the area to be cut several times, radiating continuously. Preferably however, during the cutting a physical quantity relating to the cutting is measured, and in dependence of that quantity the power of the laser is adjusted. This gives the advantage that no separate tests are necessary, and that, with possibly moved contact pads, there may still be cut correctly. This ensures a more flexible cutting process. All this has already been explained in detail above.

Advantageously, the physical quantity comprises radiation emanating from the composite structure and/or the carrier film. Preferably the spectrum of the radiation is measured. Here the radiation of the composite structure comprises at least radiation from the contact pads and also radiation from either the encapsulating plastic or the substrate, or combinations thereof, although not necessarily at the same time. The advantages of these embodiments have already been explained above.

In the embodiment in which the electrical separation and the mechanical disconnection takes place in one processing step an even better quality may be ensured. Nevertheless other methods for separating and/or mechanical disconnecting are also possible. Here, sawing by means of a fast rotating saw blade may be contemplated. Preferably, this last method is only applied for mechanical disconnecting. After all, here the electrical connections have already been disconnected, preferably by a laser cutting operation so there is no further risk of smearing of metal.

Hereinafter, the invention will be further explained with reference to the accompanying drawings, in which:

- Figure 1 shows in cross section, a schematic cutting operation on a composite structure by means of a device according to the invention; and

- Figure 2 shows in cross section, another embodiment of a cutting operation according to the invention.

The mutual proportions in the drawing have not been reproduced correctly. In particular, for clarity's sake, the composite structure has been reproduced on an enlarged scale.

In figure 1, a composite structure is indicated with 1. This comprises a substrate 2, here a plastic material, onto which a number of ICs 3 are mounted on elevations 2. The electrical connections of the ICs 3 are connected to contact pads 4 by means of metal wires 5. The ICs 3 are encapsulated with an encapsulating plastic 6. The elevations 2 and/or contact pads 4 may, at the bottom side, be provided with recesses 7 that are also filled with encapsulating plastic 6 and serve as anchorage for the encapsulating material. Further, chain lines 8 indicate cutting lines along which the various encapsulated ICs 3 are to be separated from each other.

9 indicates a laser that emits a laser beam 10. With 11, a control system for control of the power of the laser 9 is indicated. 12 is a cloud of evaporated material that emits radiation 13 in all directions. This radiation 13 can be detected by means of a light-sensitive element 14 that is connected to a spectroscope 15. The spectroscope 15 is connected to the control assembly 11.

The composite structure 1 in Figure 1 is cut by means of the laser beam 10. The intended cutting plane comprises a plane through cutting line 8. In this way, the laser beam 10, as seen from above, first has to cut through a layer of encapsulating material 6, for instance a thermo-setting resin, then through the material of the contact pads 4, for instance copper, and then through a layer of substrate 2, for instance the plastic material. This may also be e.g. ceramic material. The power of the laser required for these materials can be very different. Therefore, the power of the laser 9 is to be adjusted as soon as a material transition is detected by means of the measurement means 14 and 15.

In the composite structure 1 the contact pads 4 do not form a solid plane. The contact pads 4 alternate with parts at which only encapsulating material 6 is present on the substrate 2. Incidentally the contact pads 4 are often very thin, for instance some micrometers. In that case they are not provided with recesses 7 at the bottom. It is also possible that a part of the substrate has been processed in such a way, for instance by etching, that encapsulating material encapsulates it on both sides . In these cases the cutting operation will proceed in a different way than during the cutting of the first mentioned parts of the composite structure 1, because first encapsulating material, then material of the contact pads and/or the substrate, and then again encapsulating material is cut. This mainly relates to those parts of the contact pads where there are recesses. Of course a part of the contact pads must remain free from covering material to make electrical connections possible later on.

A type of laser possibly suited in this connection is a so-called excimer laser. This emits pulsed laser radiation, mostly in the ultraviolet region, with a wavelength shorter than 400 nm. These are mostly powerful lasers, the produced wavelength being absorbed well by many different materials. Of course the laser is not limited to the excimer laser. Other types, like for instance a YAG-laser, could also be suitable for application in a device according to the invention.

Figure 2 shows a different embodiment of a cutting operation according to the invention. Similar parts are indicated with spectra like reference numerals. In this composite structure 1, the ICs 3 are encapsulated with an encapsulated plastic 6. Here, the substrate 2 is a lead frame. The lead frame can be any lead frame known in the state of the art. Here for instance it is a copper lead frame. 16 indicates a carrier film, that is attached to the composite structure 1.

In the embodiment shown here, the lead frame side of the composite structure is directed towards the laser. The composite structure 1 is cut with the help of the laser beam 10. The intended cutting plane comprises a plane through cutting line 8. In this way the laser beam 10, as seen from the top, first has to cut through the material of the contact pads 4, in this case copper, and then through a layer of encapsulating material 6, for instance a thermo-setting resin. Finally, it is possible to also cut through the carrier film 16. This, however, is not necessary, and the mechanical and electrical encapsulated ICs 3, disconnected mechanically and electically, can also be removed from the carrier film in another way. This may for instance take place by peeling off the carrier film 16, or severing the connection between carrier film 16 and composite structure 1 in another way.

The performed cutting operation can be of many kinds. E.g., the complete composite structure 1 can be divided by cutting into separate encapsulated electronic components. Thereto the laser beam 10 must cut through the complete composite structure 1. Mostly this is the last step in the production process.

It is also possible to interrupt the cutting operation before the complete composite structure 1 has been cut . This is for instance desired if the electronic components 3 must be tested as an assembly. Thereto the electrical connections between for instance the contact pads 4 must be disconnected, without losing the mutual mechanical coherence and position of the electronic components 3. In that case the cutting operation must go through at least the complete contact pads 4, without completely cutting the substrate 2 and/ or the encapsulating material 6 or possibly the carrier film 16. By means of a device according to the invention this may simply be accomplished by interrupting the cutting as soon as the measured spectrum corresponds to that of the substrate, the encapsulating material 6 or if necessary the carrier film 16.

The electronic components, insulated electrically in this way, may then be tested. Dependant on the result of the test, the electronic components 3 are marked. Next the electronic components 3 that do not satisfy the test may be separated from the electronic components 3 that do meet the test.

For instance this separation can be brought about by storing the coordinates of the approved electronic components 3, and cutting out the substrate 2 and/or the encapsulating material 6is cut in such a way, for instance by laser, that the corresponding electronic component3is removed from the composite structure 1.

As described, it is also possible to attach a separate carrier film to the substrate 2, or, for instance, onto the covering material 6, and to disconnect the various electronic components 3 from each other in one cutting operation. In other words, in that case, the incisions with the laser beam 10 are so deep that all layers of the composite structure 1 are cut, the mechanical connections of the carrier film 16 however remaining in tact. In fact, the carrier film now takes over the function of the substrate, for instance lead frame, as described above. However, the quality of the cuts can be further improved in this way because they are made in one motion. The risk of intermediate displacement, and thereby possibly damaged electronic components 3, is reduced.

CLAIMS

1. Method for cutting a composite structure comprising one or more electronic components, in particular integrated circuits, using a laser, characterized in that during the cutting of the material of the composite structure, a physical quantity relating to the cutting is measured, and that the power of the laser is adjusted depending on said physical quantity.

2. Method according to claim 1, characterized in that the physical quantity comprises radiation emanating from the composite structure.

3. Method according to claim 2, characterized in that the spectrum of radiation emanating from the composite structure is measured.

4. Method according to one of the preceding claims, characterized in that the laser is a pulsed laser.

5. Device for the cutting of a composite structure comprising one or more electronic components, in particular integrated circuits, the device at least comprising

- a laser,
- control means for controlling the power of the laser,
- support means for the composite structure,
- transport means to move the composite structure and the laser with respect to one another,

characterized in that the device further comprises measuring means for measuring of a physical quantity relating to the cutting during the cutting of the material of the composite structure.

6. Device according to claim 5, characterized in that the measuring means comprise means for measuring a part of the spectrum of radiation emanating from the composite structure.

7. Device according to claim 6, characterized in that the control means for controlling the power of the laser are coupled to the

measuring means.

8. Composite structure, comprising one or more electronic components, in particular integrated circuits, obtainable by a method according to one of claims 1-4.

9. Method for testing electronic components accomodated in a composite structure, the method comprising the steps of:
- providing a composite structure comprising a leadframe onto which at least one electronic component has been mounted and at least two contact pads, which are each connected electrically to an electronic component and at least one other contact pad, wherein the leadframe, the at least one electronic component and the contact pads are at least partially encapsulated with encapsulating plastic;
- cutting of the electrical connections between each of the contact pads belonging to at least one electronic component, and the other contact pads; and
- testing of the electronic component thus isolated.

10. Method according to claim 9, further comprising the steps of:
- marking the tested electronic component, depending on the result of the testing; and
- cutting the tested and marked electronic component out of the composite structure.

11. Method according to claim 9 or 10, further comprising the steps of:
- mounting the composite structure, at one side thereof, onto support means; and
- disconnecting the electrically isolated electronic component mechanically from the composite structure.

12. Method according to claim 11, characterized in that the support means are selected from a carrier film, a supporting mold, a supporting mold having vacuum suction means, or a combination thereof.

13. Method according to claim 11 or 12, characterized in that the step of cutting of the electrical connections and the step of mechanical disconnection take place in one processing step.

14. Method according to one of claims 9-13, characterized in that the cutting of the electrical connections is brought about using a laser.

15. Method according to claim 14, characterized in that during the cutting a physical quantity relating to the cutting is measured, and in that the power of the laser is adjusted depending on that quantity.

16. Method according to claim 14, characterized in that the physical quantity comprises radiation emanating from the composite structure and/or the carrier film.

17. Method according to claim 16, characterized in that the spectrum of the radiation is measured.

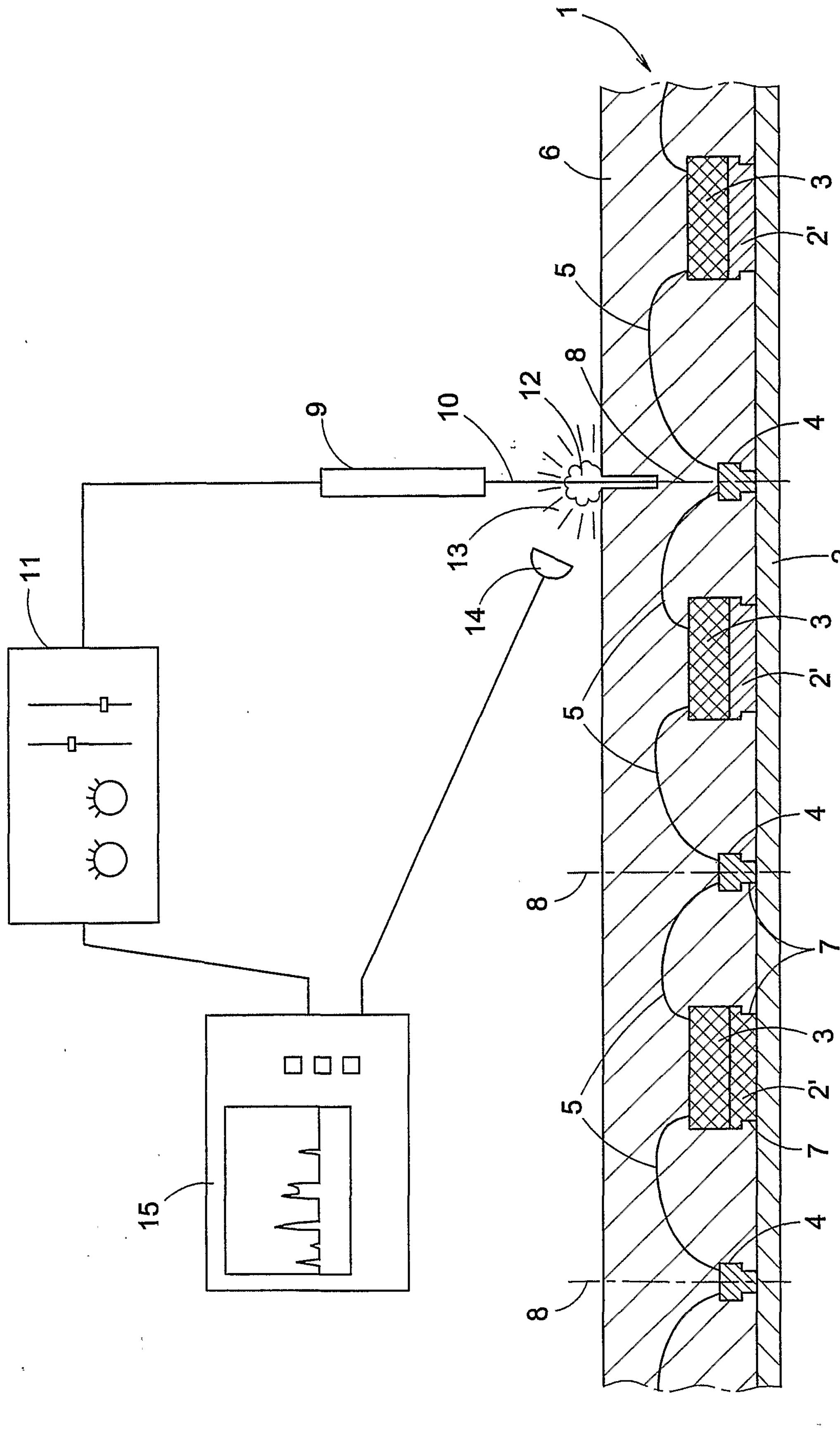

Fig. 1

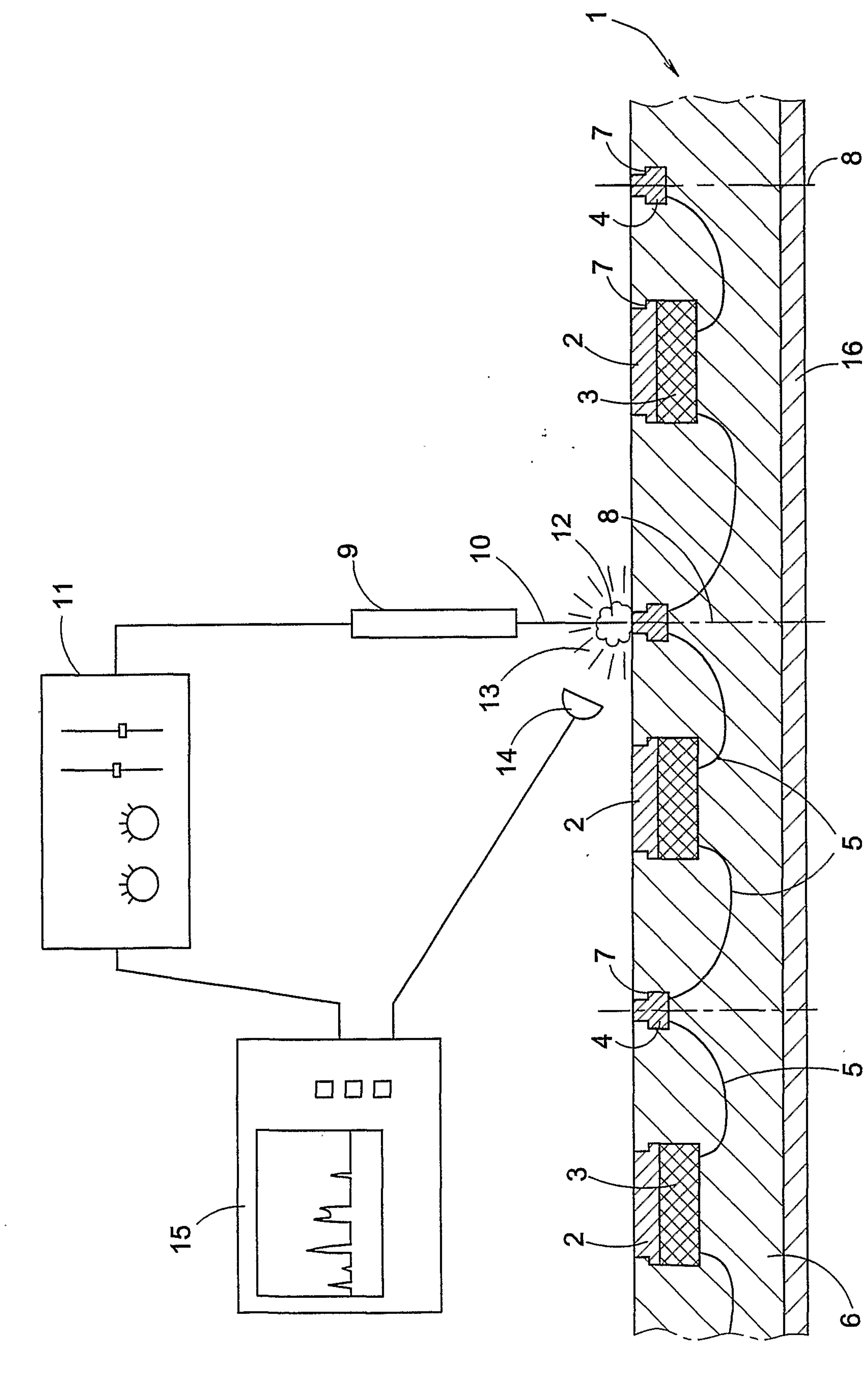

Fig. 2